AVIONICS BASED RUNWAY INCURSION PREVENTION

NASA SBIR

PHASE I

FINAL REPORT

NAS1-03018

NASA LANGLEY RESEARCH CENTER

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Phase I Project Summary

Firm: Rannoch Corporation
Contract Number: NAS1-03018
Project Title: Avionics Based Runway Incursion Prevention

Identification and Significance of Innovation:

This research involves the adaptation of an aircraft based runway incursion advisory and alerting system for general aviation applications. PathProx is a runway incursion advisory and alerting system developed by Rannoch Corporation for air carrier operations. The work under Phase I of this SBIR included the definition of the developmental needs for adapting the PathProx conflict detection and alerting collision avoidance algorithms to General Aviation (GA) operations. Systems currently being deployed by the FAA are based on a ground infrastructure where runway incursion conflict alerts generated by the system are provided to ATC. Under this operational scenario the pilot is not provided with conflict alert information in the cockpit, leaving the aircraft dependent on the ground ATC infrastructure and human response. A General Aviation runway incursion advisory and alerting system will provide the following safety benefits:

- Reduction in the likelihood of near collisions resulting from runway incursions.
- Improved pilot response in taking evasive actions following incursions.
- Provision of runway incursion alerting at airports not equipped with surface surveillance systems
- Provision of runway incursion alerting at uncontrolled (non-towered) airports

Technical Objectives and Work Plan:

The specific technical objectives of the Phase I research were:

a) Define runway incursion operational scenarios for GA
b) Determine adaptations required to apply PathProx to GA
c) Determine requirements for testing and certification

Following is a list of the tasks accomplished under Phase I.
a) Determination of Operational Scenarios for GA
b) Analysis of GA Airport Operations
c) Analysis of GA Aircraft Characteristics
d) Analysis of Pilot Human Factors
e) Determination of Adaptations Required to Apply PathProx to GA
f) Determination of Requirements for Testing & Certification

Technical Accomplishments:

All of the technical objectives that were identified were accomplished, including the list of tasks in the work plan. The results of the research under Phase I indicates that the technical objective of adapting PathProx for use with GA aircraft is feasible. A number of adaptations and modifications have been identified that will need to be incorporated and tested.

NASA Application(s):

There are two current NASA programs where GA runway incursion alerting has application – Aviation Safety and the Small Aircraft Transportation System (SATS). The Aviation Safety program includes the Runway Incursion Prevention System (RIPS), which has been addressing runway incursion prevention for air carrier operations. This program also includes General Aviation operations, however there has no work done to date on the GA application. The PathProx GA implementation would fulfill that role.

GA runway incursion alerting would be an augmentation to the SATS program. Although the SATS operational concept does not include runway incursion alerting, it does include conflict detection and alerting in the terminal area – under the High Volume Operations (HVO) part of the SATS program. PathProx runway incursion alerting would extend the alerting to include the airport surface.

Non-NASA Commercial Application(s):

The ultimate product that would result from this research has potential application to general aviation, because runway incursions are a significant problem at all classes of airports. A runway incursion alerting system is currently not available to any class of aircraft. It is envisaged that the PathProx alerting algorithms would be a supplement to several other technologies that are currently under development. These other technologies are GPS, ADS-B, and CDTI. As the infrastructure for these technologies is established, it will be easy to integrate aircraft based PathProx into the avionics.

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Part 1 Table of Contents

Part 2 Identification and Significance of the Innovation

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PathProx was originally developed by Rannoch under a cooperative agreement with NASA (Contract NCC-1-347). Under that agreement PathProx comprises the Runway Incursion Advisory and Alerting System (RIAAS), and is a key element of NASA's Runway Incursion Prevention System (RIPS). RIPS is intended for application to commercial aircraft. As such the development of PathProx has assumed an infrastructure and set of operational scenarios applicable to air carrier operations. It is not currently intended for General Aviation operations. That will require some specific adaptations that have been defined through the research conducted under this SBIR.

Part 3 Technical Objectives

The specific technical objectives of the Phase I research were:

d) Define runway incursion operational scenarios for GA
e) Determine adaptations required to apply PathProx to GA
f) Determine requirements for testing and certification

Part 4 Work Plan

4.1 Technical Approach

The technical approach was to divide the research into the three areas of the technical objectives stated in Part 3.

4.2 Task Descriptions

Following is a list of the tasks accomplished under Phase I.

f) Determination of Operational Scenarios for GA
g) GA Airport Operations
h) GA Aircraft Characteristics
i) Pilot Human Factors
j) Determine Adaptations Required to Apply PathProx to GA
k) Determine Requirements for Testing & Certification

4.3 Meeting the Technical Objectives

The results of the research under Phase I indicates that the technical objective of adapting PathProx for use with GA aircraft is feasible. A number of adaptations and modifications have been identified that will need to be incorporated and tested.

4.4 Task Labor Categories and Schedules

The personnel hours by task area are shown in Table 1. The schedule and the three main task areas are shown in Figure 1.

Table 1. Task Hours

Key Personnel	Task 1 Determination of Operational Scenarios	Task 2 Adaptations Required for GA	Task 3 Requirements for Testing & Certification
Principal Investigator	150	150	30
Airport Surveillance Expert	100	75	25
Junior Engineer	100	100	

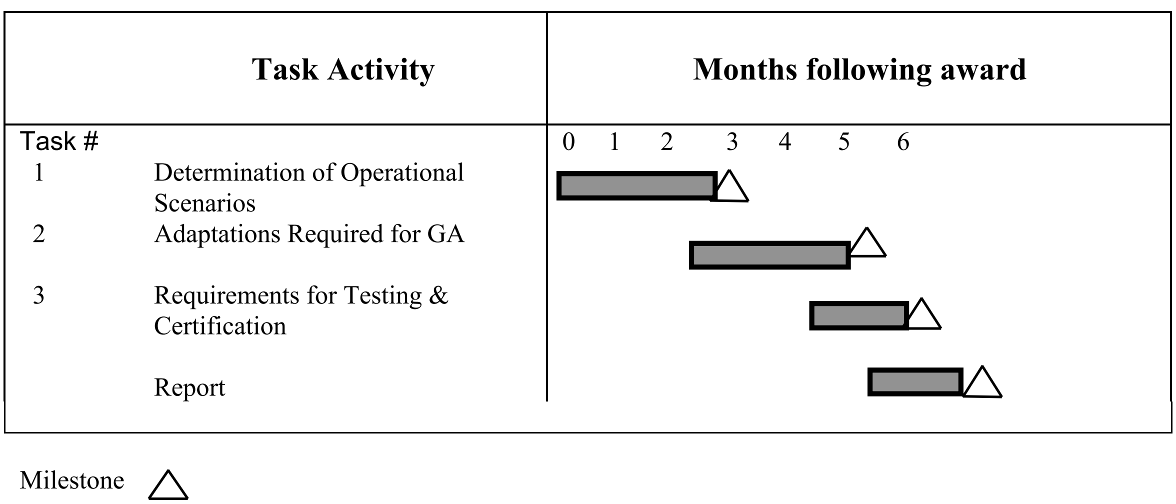

Figure 1. Program Schedule and Milestones

Part 5 Potential Applications

5.1 Potential NASA Applications

There are two current NASA programs where GA runway incursion alerting has application – Aviation Safety and the Small Aircraft Transportation System (SATS). The Aviation Safety program includes the Runway Incursion Prevention System (RIPS), which has been addressing runway incursion prevention for air carrier operations. This program also includes General Aviation operations, however there has no work done to date on the GA application. The PathProx GA implementation would fulfill that role.

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5.2 Potential Non-NASA Applications

The ultimate product that would result from this research has potential application to general aviation, because runway incursions are a significant problem at all classes of airports. A runway incursion alerting system is currently not available to any class of aircraft. It is envisaged that the PathProx alerting algorithms would be a supplement to several other technologies that are currently under development. These other technologies are GPS, ADS-B, and CDTI. As the infrastructure for these technologies is established, it will be easy to integrate aircraft based PathProx into the avionics.

Part 6 Contacts

6.1 Key Contractor Participants

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6.2 Key NASA Participants

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Susan McClain, Contracting Officer, NASA LaRC
Robert Yang, Center SBIR Program Manager, NASA LaRC

6.3 NASA and Non-NASA Advisors

None

Part 7 Technical Activities

7.1 Cumulative Technical Activities

Following is a description of the results of the research activities for Phase I.

7.1.1 Determination of Operational Scenarios for GA

The current version of PathProx for Air Carrier operations has incorporated all of the potential runway incursion scenarios, which are largely independent of aircraft type. There are other operational characteristics however that are different for GA. The four most common runway incursion scenarios are:

- Departing; Taxi crossing
- Landing; Departing on same runway (tail chase)
- Landing; Departing on crossing runway
- Landing; Taxi crossing

Figure 2 illustrates these scenarios. The scenario in Figure 2A is when an aircraft taxis onto an active runway while an arrival aircraft is attempting to land. The scenario in Figure 2B is also when an aircraft taxis onto an active runway, this time when a departing aircraft is attempting to takeoff. The scenario in Figure 2C occurs when there is a loss of separation between a departing aircraft and an arrival. The scenario in Figure 2D occurs when there is a conflict on a converging runway operation. This includes Land and Hold Short Operations (LAHSO), where aircraft are allowed to land and hold short of the intersection of the converging runway, while allowing traffic to operate independently on the other runway.

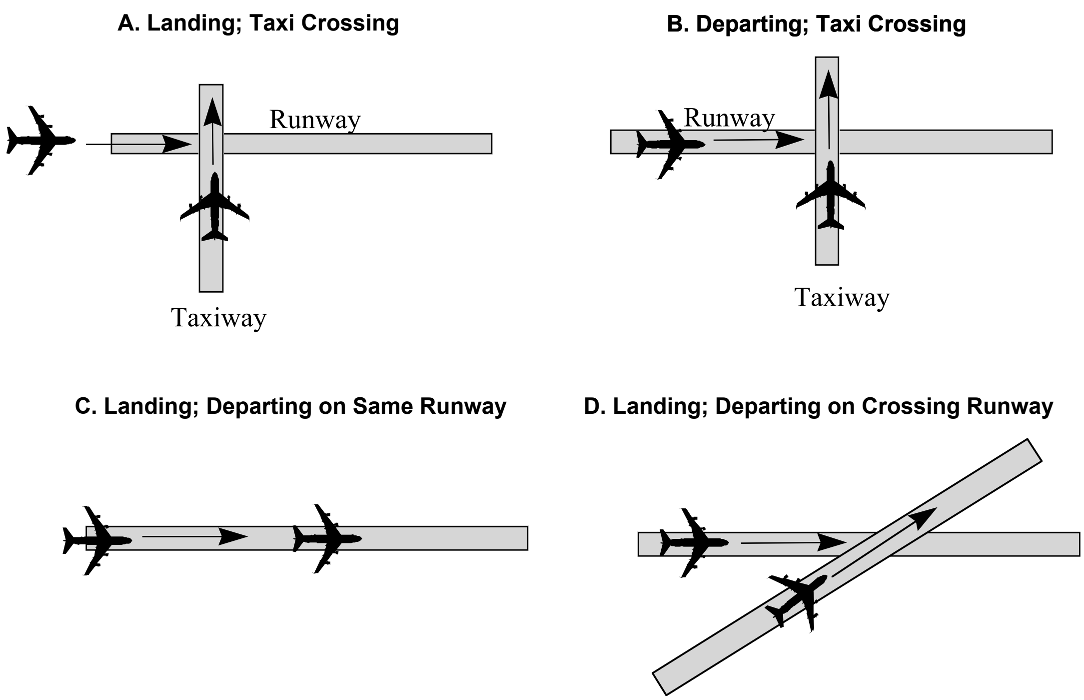

Figure 2. Most Common Runway Incursion Scenarios

The complete list of all scenarios currently included in PathProx are shown in Table 2. PathProx is designed to handle over forty different runway incursion scenarios. A review of the incursion scenarios in Table 2 concluded that the same scenarios were applicable to GA operations. Therefore no change is required in defining the basic scenarios. However there will be changes required in many of the scenarios with regard to the alert criteria. Those changes will be discussed further below.

Table 2. PathProx Runway Incursion Scenarios

Conflict #	Ownship State	Other Vehicle State	Conflict Type
1	Arrival	Taxi	Crossing
2	Arrival	Taxi	Tail Chase
3	Arrival	Taxi	Tail Lead
4	Arrival	Taxi	Head On
5	Taxi	Arrival	Crossing
6	Taxi	Arrival	Tail Chase
7	Taxi	Arrival	Tail Lead
8	Taxi	Arrival	Head On
9	Departure	Taxi	Crossing
10	Departure	Taxi	Tail Chase
11	Departure	Taxi	Tail Lead
12	Departure	Taxi	Head On
13	Taxi	Departure/High Speed	Crossing
14	Taxi	Departure/High Speed	Tail Chase
15	Taxi	Departure/High Speed	Tail Lead
16	Taxi	Departure/High Speed	Head On
17	Arrival	Departure/High Speed	Crossing
18	Arrival	Departure/High Speed	Tail Chase
19	Arrival	Departure/High Speed	Tail Lead
20	Arrival	Departure/High Speed	Head On
21	Departure	Arrival	Crossing
22	Departure	Arrival	Tail Chase
23	Departure	Arrival	Tail Lead
24	Departure	Arrival	Head On
25	Arrival	Arrival	Crossing
26	Arrival	Arrival	Tail Chase
27	Arrival	Arrival	Tail Lead
28	Arrival	Arrival	Head On
29	Departure	Departure/High Speed	Crossing
30	Departure	Departure/High Speed	Tail Chase
31	Departure	Departure/High Speed	Tail Lead
32	Departure	Departure/High Speed	Head On
33	Taxi	Taxi	Crossing
34	Arrival	Stopped	Head On
35	Arrival	Stopped	Tail Lead
36	Departure	Stopped	Head On
37	Departure	Stopped	Tail Lead
38	Taxi	Stopped	Head On
39	Taxi	Stopped	Tail Lead
40	Stopped	Arrival	Head On
41	Stopped	Arrival	Tail Lead
42	Stopped	Departure/High Speed	Head On
43	Stopped	Departure/High Speed	Tail Lead
44	Stopped	Taxi	Head On

The work on determining operational differences was divided into three areas - airport operations, aircraft characteristics, and pilot human factors.

7.1.2 Airport Operations

The differences that were identified relative to airport operations include the following:

a) Reduced in-trail separation for GA aircraft

The in-trail separations on approach are smaller for GA aircraft than with air carrier. The separations for air carrier are driven by wake vortex considerations (see Table 3) [Ref. 1, para. 7-3-9]. This is not the case for GA. The minimum separation for any air carrier operation is 2.5 NM, which is primarily driven by runway occupancy time. The design of PathProx alerting algorithms takes into account the assumed nominal separations for the larger aircraft. As can be seen from the table, there are no requirements for small (GA) aircraft landing behind similar sized aircraft. And, there is no minimum for GA only operations relative to runway occupancy time considerations.

Table 3. Wake Vortex Separation Requirements

	Leading Aircraft		
Trailing Aircraft	Large	757	Heavy
Small	4 NM	5 NM	6 NM
Large	--	4 NM	5 NM
Heavy	--	4 NM	4 NM

The wake vortex separation requirements apply only during IMC (Instrument Meteorological Conditions) operations. During Visual Meteorological Conditions (VMC) operations the separation requirements do not apply, leaving it up to the pilot's discretion to maintain adequate separation. Therefore, for GA operations this means that the aircraft can potentially have very short separations. The key issue for in-trail is how close an approaching aircraft can be while the leading aircraft is still on the runway. In those situations the minimum separation is driven by "Same Runway Separation," as defined in the FAA ATC Handbook [Ref. 2]. The separation requirements depend upon the aircraft categories as defined below:

Aircraft Categories:
Category I: Single Engine < 12,500 lbs
Category II: Twin Engine < 12,500 lbs
Category III: All Others (>12,500 lbs)

GA aircraft would be classified as both Category I and II. The key requirement there is that Category I (small GA) aircraft need only 3,000 feet separation behind other landing or departing aircraft (see Figures 3, 4, and 5). This means that the trailing aircraft can be crossing over the threshold while the lead aircraft is still rolling out down the runway, as long as it is greater than 3,000 ft down the runway. In cases involving Category II aircraft the required separation is 4,500 ft. This requirement applies only to towered airports.

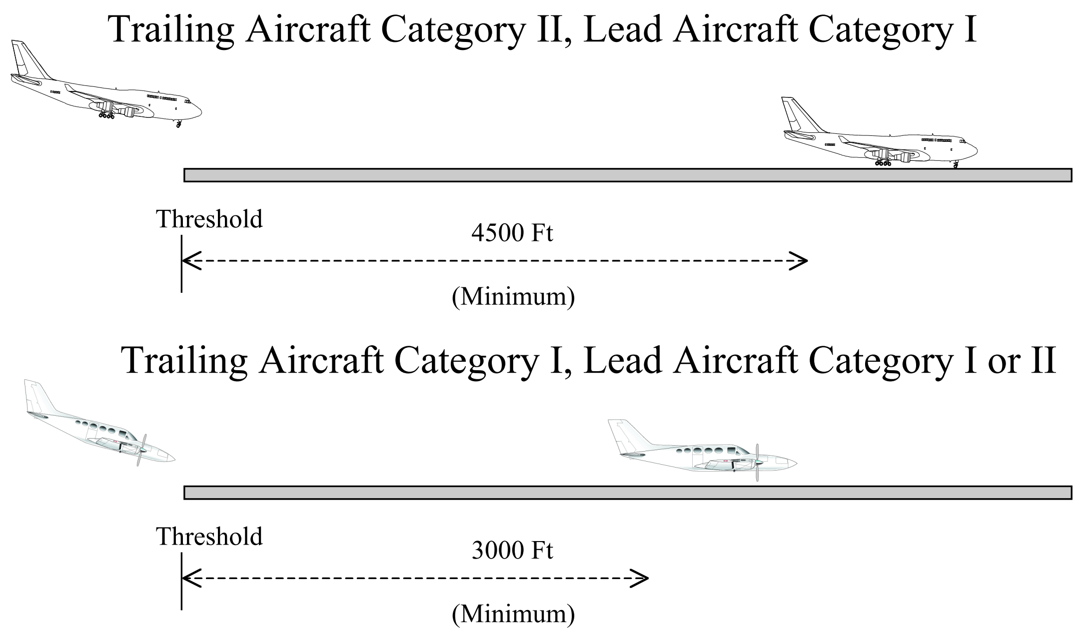

Figure 3. Runway Separation Requirements for Landing Aircraft

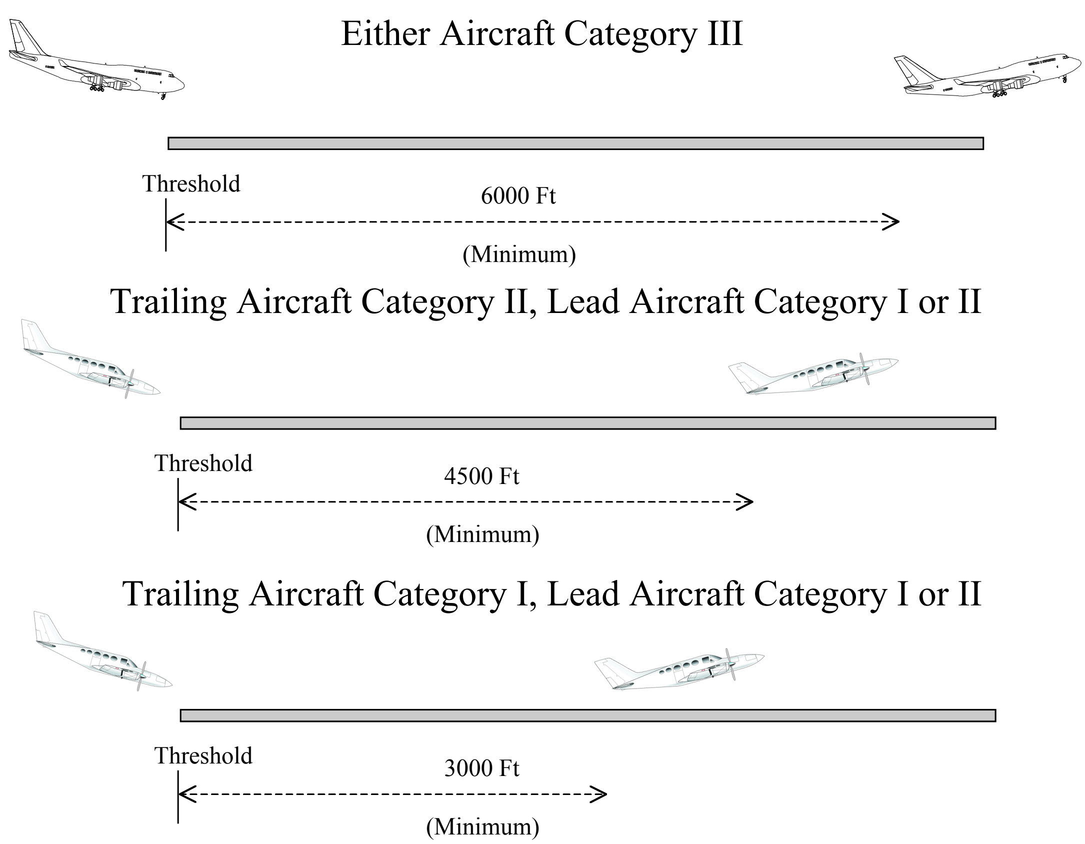

Figure 4. Runway Separation Requirements for Landing and Departing Aircraft

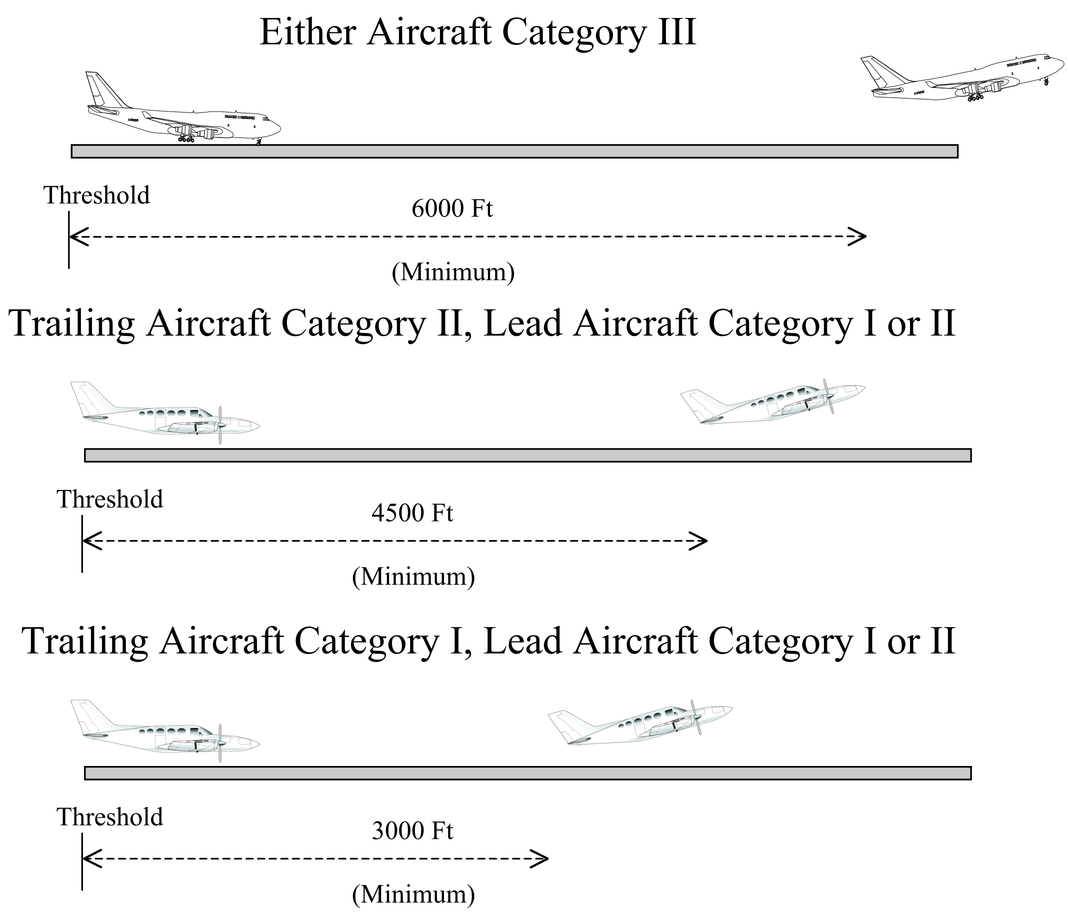

Figure 5. Runway Separation Requirements for Departing Aircraft

There are no specific rules applicable to operations at non-towered (Class E airspace) airports or to uncontrolled (Class G airspace) airports. For operations at airports without a control tower, it is basically the pilot's best judgment to maintain safe separation. A typical guideline might be as follows:

Arrival/Arrival scenario: The pilot of the trailing aircraft would ensure that his aircraft does not touchdown until the lead aircraft is clear of the runway. This would be true for shorter runways (< 5,000 ft), which would encompass most GA airports. For the case where it was a longer runway, the pilot might allow for the lead aircraft to be still on the runway when he touches down, as long as the other aircraft was near the stop end of the runway.

Arrival/Departure scenario: The pilot of the arriving aircraft would ensure that his aircraft does not touchdown until the departing aircraft has lifted off the runway. As for the Arrival/Arrival scenario, this would be true for shorter runways (< 5,000 ft), which would encompass most GA airports. For the case where it was a longer runway, the pilot *might allow for the departing aircraft to be still on the runway when he touches down, as long as the other aircraft was near the stop end of the runway.*

The separation required for operations on crossing runways are also less stringent for GA, again because of reduced consideration for wake vortex.

Table 4 lists the combinations of airport and aircraft types that the GA PathProx implementation will be required to operate. Operations where there is a mix of GA and air carrier aircraft may present some issues due to differences in alert thresholds. This is discussed further in section 2.2.2.

Table 4. Operational Combinations of Airports and Aircraft Types

	Other Traffic Types	
Airport Type	**GA**	**Air Carrier**
Large Towered	**Yes**	**Yes**
Small Towered	**Yes**	**No**
Small Non-Towered	**Yes**	**No**

b) Shorter final approach path intercept

Air carrier aircraft typically have final approach segments greater than 5 NM. They rarely will be less than 3 NM, except for special noise abatement procedures, such as the river approach to Washington Reagan National Airport. GA operations can have final approach segments very close to threshold, especially during VMC operations.

c) Crossing Runways

There is a higher prevalence of Land and Hold Short Operations (LAHSO) at major airports. Many of these involve short runways where GA and other small commuter aircraft operate. Although LAHSO is not a typical operation at predominately GA airports, there are other issues there because of the less controlled nature of the operations, especially at non-towered airports. This means that there are some differences between GA only operations and mixed operations between GA and air carrier. The research is on-going to identify possible differences with non-towered airports for crossing runways and other aspects.

d) Hold Lines

The hold lines at smaller GA airports have distances to the runway shorter than those with air carrier aircraft. This results in smaller separations between aircraft on the taxiway and runway, which allows for shorter times for conflicts to occur and shorter reaction times for evasive maneuvers. Another issue is that the databases for GA airports may not include the hold lines, but instead may be limited to the runways. While this is sufficient to provide a minimal capability for incursion alerting, further evaluation is needed to determine the impact and appropriate design change.

7.1.3 Aircraft Characteristics

There are several characteristics that are different for GA aircraft from air carrier. These include:

a) Approach Speed

Approach speeds are much slower with GA aircraft. While air carrier aircraft have typical approach speeds between 120 and 150 kts, GA aircraft are usually less than 100 kts, and can be as low as 75 kts.

b) Takeoff Speed

The rotation speeds for takeoff are also much slower with GA aircraft. While air carrier aircraft have typical rotation speeds above 120 kts, GA aircraft are usually less than 100 kts, and can be as low as 50 kts.

c) Acceleration

Acceleration rates during takeoff are lower for GA. Air carrier aircraft are usually greater than 2 m/s^2. GA aircraft can be as low as 1 m/s^2.

c) Climb Rates

Climb rates are lower for GA. Air carrier aircraft can typically climb greater than 2,000 fpm (feet per minute). Some GA aircraft can only climb as low as 700 fpm.

d) Evasive Procedures

The ability of GA aircraft to maneuver during evasive maneuvers is better (quicker) than air carrier. This means that the aircraft can execute a go-around more quickly than can an air carrier aircraft. Similarly rejected takeoffs (RTOs) can be executed in shorter times. The time to stop following an alert during taxi will also be shorter.

7.1.4 Pilot Human Factors

The biggest difference between GA operations and air carrier relative to the pilot is that air carrier aircraft always have a minimum two person crew, whereas GA are primarily single pilot operations. This is likely to have some impact on some of the human factors issues, primarily with regard to the annunciation of alerts. One assumption made in the current design of PathProx for air carrier operations is that with a two person crew, one of the pilots would monitor the surface moving map display for situational awareness. When an alert occurs the pilot would be able to quickly assess the conflict, and determine any course of action required. This is most applicable for Runway Traffic Alerts, when evasive action is not required, but may be desired in some circumstances. With only a single pilot he would not necessarily be able to monitor the map display continuously. This means that situational awareness may not be as good as with two person crews. The consequence of this is that the pilot response to an alert may take longer in a single pilot operation. This could have an impact on safety.

A closely related issue concerns the use of two level alerting. PathProx provides two types of alerts. A Runway Traffic Alert (RTA) is generated when the ownship aircraft is projected to be involved in a runway incursion with other traffic. The Runway Traffic Alert acts to caution the pilot of a potential incursion. A Runway Conflict Alert (RCA) is provided when an actual runway incursion has been detected, and there is potential for collision. An RCA indicates that the aircraft involved in the conflict need to take evasive action to avoid the potential collision. One purpose for the RTA is to make the pilot aware of a pending conflict, so that if an RCA is generated subsequently, the pilot is able to respond quickly in taking evasive action. The two levels of alerts may be even more advantageous in some circumstances to single pilot aircraft, since the second pilot is not present to monitor situational awareness. The RTA can help to provide situational awareness. Another reason for this is that with operations at non-towered airports GA pilots will not have the benefit of air traffic control advisories. The provision of RTAs can alert pilots to potential conflicts.

On the other hand, with a single pilot operation, it may be more difficult for the pilot to ascertain his situational awareness as quickly as when there are two pilots. This may minimize the usefulness of the RTA.

7.1.4 Determine Adaptations Required to Apply PathProx to GA

Two Level Alerting

Based on the initial analysis of human factors issues (section 7.1.4), there will not be any fundamental change required in PathProx regarding the general philosophy of providing two levels of alerts. However, based on the issues associated with single pilot operations, one aspect of the alerting algorithms that will be changed is to provide only conflict alerts when there is a short time interval between the traffic alert and conflict alert. During the simulator and flight test of PathProx it was found there were some incursion scenarios where the time interval between the two alerts was very short (1-2 seconds). Pilot feedback indicated that this was undesirable, therefore in some cases the traffic alert was removed, if the conflict would require immediate evasive action anyway. This will be further reviewed to determine if there are any other scenarios with a short time interval. It will be undesirable to have short intervals for single pilot operations, since the pilot won't have enough time to react to a traffic alert, if the conflict alert occurs a few seconds later. Additional study will be required in Phase II to optimize the two level alerting for single pilot operations. One application where two level alerting may not be appropriate at all is with no map display. See the discussion under "Cockpit Display".

Alerting Algorithm Changes

The changes that have been identified based on analysis of the differences in GA operations described above include the following:

a) Reduced in-trail separation: The alert thresholds for arrival scenarios will be modified such that the alerts will occur with the aircraft closer to the runway. One of the issues is how will PathProx determine which set of criteria to apply, depending upon the type of airport. Two potential indicators are the airport and maximum runway length for the airport, both of which are contained in the database.

b) Reduced same runway separation: The alert thresholds for scenarios where the two aircraft are on the same runway will be reduced based on the standards. This is different than alerting with air carrier operations, which is based on the principle of protecting the entire runway in most cases.

c) Crossing runway operations: The alert thresholds for scenarios that may involve LAHSO operations will be modified, based on tailoring the alerts for GA aircraft flight characteristics.

d) Hold line distances: Some alert thresholds will be modified based on the shorter distances of hold lines from the runway at small airports.

e) Limited database: Alert thresholds for GA airports with no hold line information will be adjusted to account for those situations.

One other issue that requires further analysis and simulation in Phase II is the alerting where there are mixed operations of GA and air carrier aircraft. With the changes that will be made to the alert thresholds for GA, it means that when a GA and air carrier aircraft are involved in a conflict, the two aircraft will not receive alerts at the same time. This may present some operational and human factors issues. Even the current design of PathProx does not always generate alerts at the same time for the two aircraft. That is because both aircraft do not have the same information available, generally because the ownship data is more accurate and timely than the other traffic data that is provided through ADS-B or TIS. This should not be an issue because PathProx does not require coordinated alerts, and it does not give resolution advisories as does TCAS. Therefore the two aircraft can take evasive maneuvers independent of each other, which should not be an operational issue.

Systems Integration

The primary functions that are required on-board the aircraft are ownship navigation position, traffic information, runway incursion processing and alert generation, and alert annunciation. Figure 6 illustrates the avionics elements normally expected for a GA aircraft installation. Figure 7 illustrates the interfaces with other aircraft and ground systems.

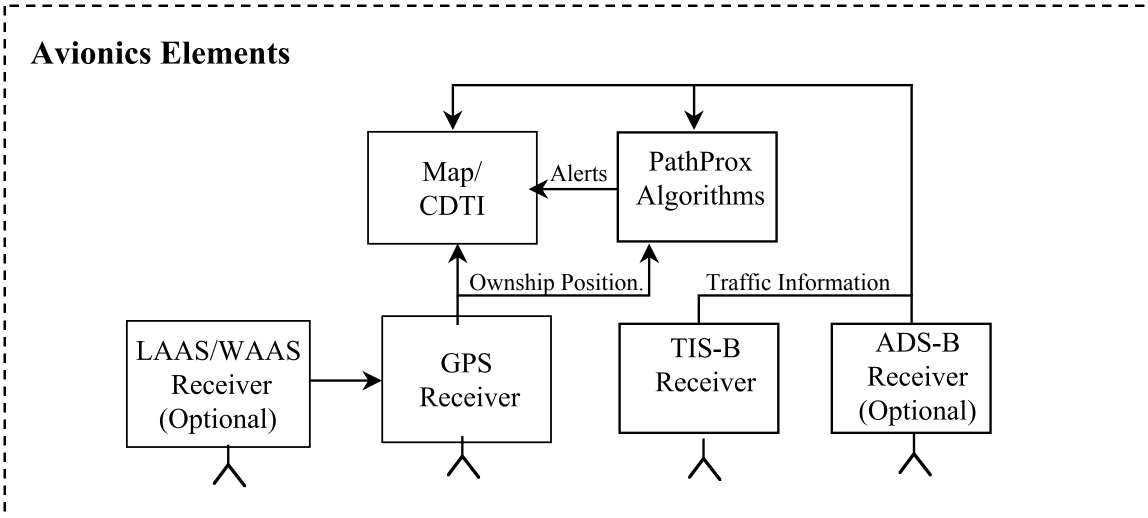

Figure 6. Aircraft Avionics Infrastructure

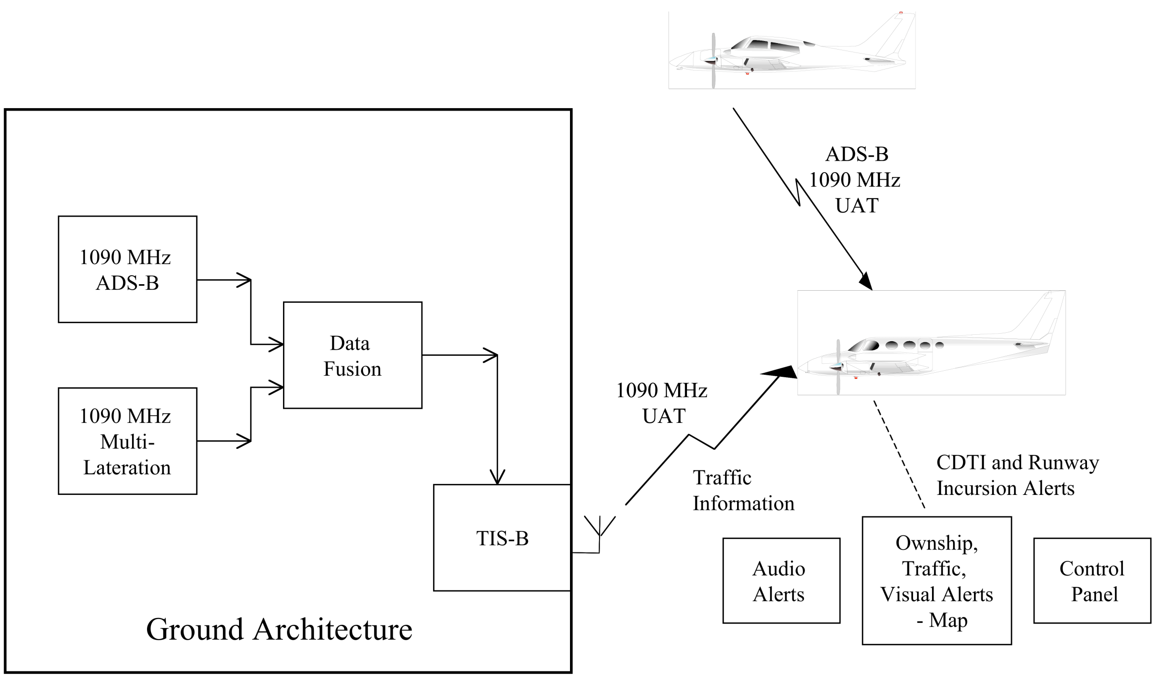

Figure 7. External Aircraft Interfaces

Following is a description of the key functions and how they might be modified for GA applications.

a) Position Information

The application of ADS-B and PathProx is dependent upon accurate position information, both the "own-ship aircraft," "other aircraft," and vehicles on the airport surface. It is assumed that aircraft (and potentially vehicle) position information will be provided by a GNSS (Global Navigation Satellite System) based system. More specifically, the current design of PathProx currently assumes the use of either the Wide Area Augmentation System (WAAS) or Local Area Augmentation System (LAAS). In addition, implementation of PathProx on the NASA test aircraft (ARIES) included integration of GPS with inertial information. One adaptation of PathProx for General Aviation is to enable incursion alerting when WAAS or LAAS is not available, and without the smoothing provided by inertial. With the removal of Selective Availability on GPS the accuracy (approximately 10 m) is now good enough to support incursion alerting. However, some adjustments will need to be made to the alert thresholds, based on having less accurate position information. This applies to both the ownship and traffic position information.

b) Traffic Information

The GA architecture will be based primarily on operation using ADS-B, but will also allow for TIS-B (Traffic Information Services – Broadcast) to be a source of information. TIS-B is a ground based system that detects aircraft through surveillance and transmits this information to other aircraft. The surveillance data can come from primary radar, secondary radar or ADS-B. The information transmitted includes aircraft identification and position. It will be assumed that the ADS-B and TIS-B information is provided in accordance with the standards developed by RTCA. From a hardware integration perspective the primary issue concerns whether the data link is Mode-S (1090 MHz) or UAT. For the most part the design of PathProx is transparent to the data link. There is some adaptation of alert thresholds, based on the assumed accuracy of the position information, depending upon the source. This will require some additional analysis to optimize the design approach for GA.

c) Cockpit display

The assumption made for the PathProx algorithm development is that the information will be displayed on a moving map. NASA has implemented one such moving map in their RIPS architecture. The approach proposed for GA adaptation is to enable PathProx alerting to function either with or without a moving map display in the cockpit. Therefore, the GA application of PathProx will be adaptable to a variety of map displays and methods of annunciating the alerts.

The version with a map probably won't require one as sophisticated as the NASA RIPS display. The RIPS display also is intended to facilitate low visibility operations, which GA will not be conducting. The map is likely to be similar to that demonstrated earlier this year by Rannoch using a Rockwell Collins surface moving map (Figure 8). In addition, PathProx will also accommodate simpler maps, such as those that can only display the airport runways, but not taxiways. It will be assumed that any map display provides the basic functionality defined in the RTCA MASPS for surface situational awareness.

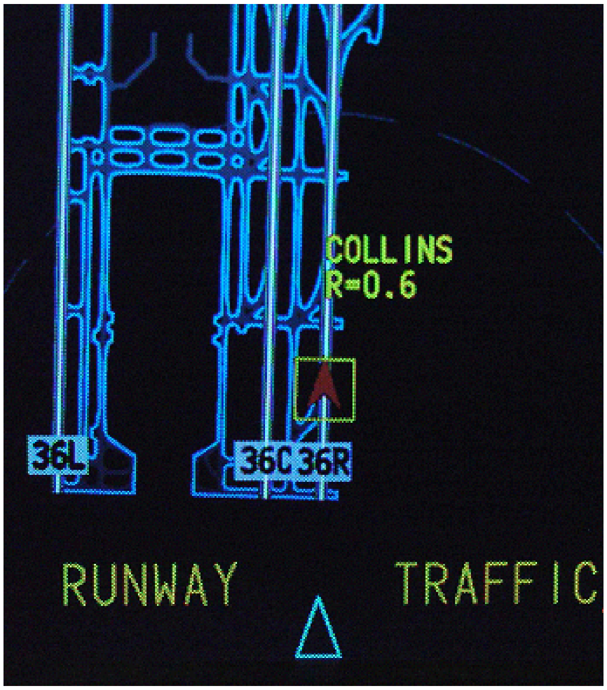

Figure 8. Typical Airport Surface Electronic Moving Map Display

The version of PathProx with no map display will provide aural alerts only. Analysis is on-going to determine what information to provide for this application. One option is to provide some information with the alert indicating the general location and state of the intruding aircraft. For example, it could indicate that the aircraft is on approach, on the runway, taking off, or taxiing. Another issue for this application is whether to provide both levels of alerts (RTA, RCA). The RTA may not be very useful without the pilot being able to know where the other aircraft is, and therefore determine the threat level. It may be more appropriate to provide only RCAs in that case.

7.1.6 Determine Requirements for Testing and Certification

Certification of the PathProx software for the GA application will be done in accordance with FAR 23.1309-1C [Ref. 3], and RTCA DO/178B [Ref. 4]. The certification requirements for Part 23 aircraft are less stringent than for air carrier.

A review of 23.1309-1C indicates that PathProx will likely be required to be certified to Level D, as defined in 178B. The classification of a PathProx failure condition should be Minor, which is defined as a "slight reduction in functional capabilities or safety margins, and a slight increase in crew workload." All classes of airplanes to which 23.1309-1C applies require Level D for Minor failures. The development process for PathProx has been accomplished with Level C as the goal. Therefore this would be less stringent, and would not impose any new requirements. The GA application should actually involve a much simplified certification process.

The requirements for Level D in DO-178B contain minimal requirements for verification and test. Therefore it is likely that the test procedures currently used with PathProx should be adequate. This will involve testing of incursion scenarios using the RIAAS simulator to verify that the high level design requirements have been satisfied.

7.2 Future Technical Activities

These will depend primarily upon the potential award of Phase II of the SBIR. Activities planned under Phase II include software development, verification testing, simulator testing, and flight test.

Part 8 Potential Customer and Commercialization Activities

8.1 Cumulative NASA Potential Customer Activities

During the last 6 months Rannoch coordinated and consulted with the following individuals regarding the Phase I SBIR research:

Denise Jones, NASA LaRC, RIPS Project Manager, 757-864-2006, denise.r.jones@nasa.gov
Sally Johnson, NASA LaRC, Manager SATS Airborne Enabling Technologies, sally.c.johnson@nasa.gov
Russ Parrish, NASA LaRC, Aviation Safety Program, 757-864-6649, r.v.parrish@nasa.gov

8.2 Cumulative Non-NASA Potential Customer Activities
During the last 6 months, Rannoch researched the market for potential partners among GA avionics manufacturers. These include manufacturers of electronic moving map displays.

8.3 Other Cumulative Commercialization Activities
None

8.4 Future Potential Customer and Commercialization Activities
Rannoch will contact potential partners among GA avionics manufacturers for integrating PathProx with commercially available avionics equipment. The intent will be to identify a moving map display that could be used for the Phase II testing and implementation.

Part 9 Resources Status

Table 5. Resource Plan

	Current Report Period
Direct Labor	$29,211.38
Direct Travel	$0.00
Direct Consultant	$0.00
Direct Materials	$126.87
Total Direct Costs	$29,338.25
Overhead 107.057%	$31,272.83
General & Admin 15.33%	$9,291.68
Total Costs	$69,902.76
Estimate of Cost to Complete the Contract	$0.00
Estimated Percentage of Physical Completion of the Contract	100%

Part 10 References

1. *Aeronautical Information Manual, FAA*, July 20, 1995.

2. *Air Traffic Control Handbook*, FAA Order 7110.65N, February 20, 2003.

3. *Equipment, Systems, and Installations in Part 23 Airplanes*, FAR 23.1309-1C, March 12, 1999.

4. *Software Considerations in Airborne Systems and Equipment Certification*, RTCA DO/178B, December 1, 1992.